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Quantification of heart rate variability by discrete nonstationary non-Markov stochastic processes

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Abstract

We develop the statistical theory of discrete nonstationary non-Markov random processes in complex systems. The objective of this paper is to find the chain of finite-difference non-Markov kinetic equations for time correlation functions (TCF) in terms of nonstationary effects. The developed theory starts from careful analysis of time correlation through nonstationary dynamics of vectors of initial and final states and nonstationary normalized TCF. Using the projection operators technique we find the chain of finite-difference non-Markov kinetic equations for discrete nonstationary TCF and for the set of nonstationary discrete memory functions (MF's). The last one contains supplementary information about nonstationary properties of the complex system on the whole. Another relevant result of our theory is the construction of the set of dynamic parameters of nonstationarity, which contains some information of the nonstationarity effects. The full set of dynamic, spectral and kinetic parameters, and kinetic functions (TCF, short MF's statistical spectra of non-Markovity parameter, and statistical spectra of nonstationarity parameter) has made it possible to acquire the in-depth information about discreteness, non-Markov effects, long-range memory, and nonstationarity of the underlying processes. The developed theory is applied to analyze the long-time (Holter) series of RR intervals of human ECG's. We had two groups of patients: the healthy ones and the patients after myocardial infarction. In both groups we observed effects of fractality, standard and restricted self-organized criticality, and also a certain specific arrangement of spectral lines. The received results demonstrate that the power spectra of all orders (n=1,2, ...) MF m(n)(t) exhibit the neatly expressed fractal features. We have found out that the full sets of non-Markov, discrete and nonstationary parameters can serve as reliable and powerful means of diagnosis of the cardiovascular system states and can be used to distinguish healthy data from pathologic data.